A DISSERTATION FOR THE DEGREE OF MASTER

Esophageal Insufflation Computed Tomography in Normal Dogs

개의 전산화단층촬영에서 식도 가스 주입 기술의 평가

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Abstract

Conventional CT for hollow organs such as esophagus is of limited value in evaluating esophageal lumen and luminal walls. The goals of this study were to determine the feasibility and describe the optimal technique for esophageal insufflation computed tomography (EICT) with CO_2 insufflation alone and to develop a standardized methodology for EICT in dogs. Seven normal beagle dogs, each weighing 11.2–16.4 kg (mean, 14.27 kg) were used. EICT (unenhanced and contrast-enhanced) was performed using an electronic CO_2 insufflator at pressures of 0, 5, and 10 mmHg in sternal recumbency during transient apnea by manual hyperventilation. After acquiring CT images at each pressure, measurements of esophageal cross-sectional luminal area (cm^2) and wall thickness (cm) were performed at standardized locations (cervical, thoracic inlet, heart base, caudal intrathoracic, and abdominal segments) within the esophagus were evaluated. A value of $P < 0.05$ was considered as significant. Appropriate esophageal distention was observed at 5 and 10 mmHg, along with significant differences in the esophageal luminal cross-sectional areas at each pressure ($P < 0.05$). All dogs showed gas dilation of the stomach at a pressure of 10 mmHg and not 5 mmHg. The optimal initial insufflation pressure for EICT in this study was determined to be 5 mmHg. EICT resulted in consistent distension of

the canine esophagus and is indicated for the evaluation of esophageal and extraesophageal disease in a single setting.

Keywords: computed tomography, CO_2 insufflation, dog, esophagus

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CONTENTS

Introduction

Esophagus is a difficult anatomical area for imaging. Imaging modalities such as radiography, esophagography, ultrasound, and endoscopy play a limited role in diagnosis (Baloi *et al.*, 2013; Guiford, 2005; Kirberger *et al.*, 2012).

On the other hand, computed tomography (CT) is an important tool in the evaluation of not only the location, the degree, and the extent of esophageal lesion, but also surrounding structure (Brissot *et al.*, 2012; Kirberger *et al.*, 2015; Ulla *et al.*, 2012). In CT, the entire length of the esophagus is seen. The esophagus is round to ovoid in the cervical and thoracic regions, and more triangular in the caudal region (Petite and Kirberger, 2011). It is normally a collapsed organ, and therefore, collapse of the esophageal lumen and contraction of the muscular wall limit the information that can be obtained in terms of the extent and wall invasion using the standard unenhanced and contrast enhanced CT.

CT is a promising imaging technique for diagnostic and therapeutic strategy as well as surgical resection of esophageal tumors in human medicine. CT facilitates panoramic exploration, virtual endoluminal visualization, accurate longitudinal and axial assessment and, measurement of tumor volume as well as accurate representation of the surrounding organs. Simultaneously, it is used for the evaluation of tumor staging and metastasis (Mazzeo *et al.*, 2004; Onbaş *et al.*, 2006; Ulla *et al.*, 2013). To acquire optimal esophageal distension, several techniques are used such as effervescent granules, oral contrast agents, oxygen bag, and carbon dioxide gas (CO_2) (Liu *et al.*, 2017; Mazzeo *et al.*, 2004; Onbaş *et al.*, 2006; Ulla *et al.*, 2010, Ulla *et al.*, 2012; Ulla *et al.*, 2013). The pneumo-CT technique using CO_2 gas is considered the most appropriate to distend the esophageal lumen, but the others are suboptimal. This technique leads to continuous and sustained supply of CO_2 at a pressure of 10 and 20 mmHg during CT acquisition (Ulla *et al.*, 2012; Ulla *et al.*, 2013).

Lately, with the advent of multi-detector computed tomography (MDCT), CT has been widely used to evaluate the gastrointestinal tract in veterinary setting (Hoey *et al.*, 2013; Vignoli and Saunders, 2011). Poorly- distended gastrointestinal lumen obscures lesions such as nodules and masses and reduces the diagnostic yield.

Therefore, several techniques were developed such as CT-pneumocolonography and hydro-CT to address the diagnostic challenges (Steffey *et al.*, 2015; Terragni *et al.*, 2012; Yamada *et al.*, 2007). However, the procedures entailed mere orogastric or endotracheal intubation to distend the esophageal lumen for better delineation of the intraluminal component or any mural mass in veterinary medicine (Kirberger *et al.*, 2012; Kirberger *et al.*, 2015; Petite and Kirberger, 2011). Comprehensive data involving CT of esophageal continuous and consistent distension in dogs are unavailable, no studies have evaluated the optimal insufflation pressure for esophageal distention.

It was hypothesized that CT imaging of the esophagus during luminal insufflation of CO_2 gas (esophageal insufflation computed tomography, EICT) was a feasible, non-invasive imaging technique for optimal distension of the canine esophagus and assessment of the entire esophagus including not only the lumen and the wall but also the surrounding structures. It facilitated the reconstruction of additional images such as virtual endoscopy. Therefore, the purposes of the present study was to determine the feasibility and optimize the EICT technique to develop a standardized methodology including insufflation pressure, to delineate the esophageal lesions in dogs.

Materials and methods

1. Animals

Seven adult beagle dogs including one female and six males, each weighing 11.2 to 16.4 kg (mean, 14.27 kg; SD, ±0.68) were used. The animal care and experimental procedures were approved by the Institutional Animal Care and Use Committee, Seoul National University, Seoul (SNU−170717−1). All dogs were clinically healthy based on physical examination, complete blood count, and serum biochemistry without any evidence of clinical signs of esophageal disorders. The median body condition score was 6/9 (range, 4/9–8/9).

2. Anesthesia for CT scan

Dogs were fasted for at least 12 hrs before CT examination was performed. Anesthesia was administered intravenously according to a standardized protocol of premedication with acepromazine (0.01 mg/kg, Sedaject®, Samu Median Co., Seoul, South Korea), tramadol (2.0 mg/kg, Maritrol®, Jeil Pharm., Daegu, South Korea), and atropine

(0.01 mg/kg, Jeil Pharm., Daegu, South Korea), followed by intravenous induction with alfaxalone (2.0 mg/kg of body weight, Alfaxan®, Jurox Pty Ltd., Rutherford, NSW, Australia). It was maintenance with isoflurane (Ifran®, Hana Pharm., Seoul, South Korea) in 100% oxygen administered via an endotracheal tube. During anesthesia and CT procedures, electrocardiography, pulse oximetry, capnography, and blood pressure were recorded using a multiparameter patient monitor.

3. CT procedures

CT examination was conducted at weekly intervals for each dog. Before EICT, conventional CT was also carried out for comparative analysis. The anesthetized dogs were held in sternal recumbency on the CT table. Prior to survey CT scan, a 12 French balloon-tipped Foley urinary catheter (Yushin medical CO., LTD., Bucheon, South Korea) was introduced into the esophageal lumen, with the balloon tip inserted below the cricopharyngeal muscles. The catheter balloon was inflated with 5 mL of room air (Fig. 1). Later, the survey CT scan (Scano) confirmed the right positon of the catheter. An unenhanced scan, from the second cervical vertebra to the caudal part of the stomach, was performed during a single breath hold. A single breath hold technique was used to inducing apnea via manual hyperventilation to prevent motion artifact and decrease lung volume. Following the initial scan, EICT was established to maintain a continuous and sustained supply of CO_2 (1 L/min) with pressures at 0 (pre-insufflation), 5 or 10 mmHg using an electronic CO_2 insufflator (Endoflator™, Karl Stortz, Tuttlingen, Germany). Each insufflation pressure protocol was performed on a separate day minimally at 1-week intervals.

Images were obtained with 1-mm slice thickness using a 64-row MDCT scanner (Aquillion 64™, Toshiba, Tochigi, Japan). The scanning parameter were as follows: 120 kV, 200 mA, 0.75 s/rotation scan, helical pitch of 27.0, pitch factor of 0.844 and 1 mm intervals, followed by contiguous reconstructions. The field of view was set to cover the esophagus and stomach area (from the 2nd cervical vertebrae level to the caudal part of the stomach). Iohexol (Omnipaque 300®, GE healthcare Cork, Ireland) was injected intravenously as the contrast medium manually with a dose of 600 mgI/kg. Contrast enhanced images were obtained 30 sec after injection.

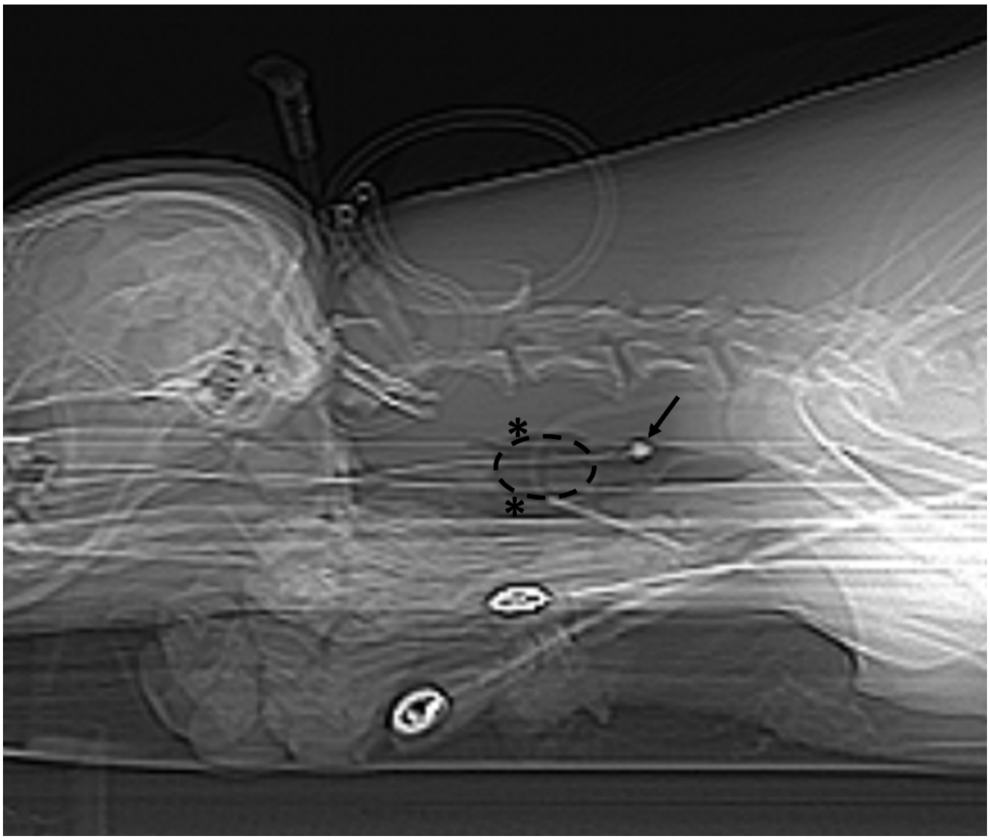

Fig. 1. A survey CT scan (Scano) showing a 12F Foley catheter in the esophageal lumen. A balloon of the catheter tip (dashed line) right below the cricopharyngeal muscles (asterisk). Arrow denotes the catheter tip.

4. Image analyses

The CT images were reconstructed for analysis and all the measurements were performed using a picture archiving and communication system (INFINITT, Infinitt Healthcare Co., Ltd., Seoul, South Korea). The esophagus was divided into five portions (cervical, thoracic inlet, heart base, caudal intrathoracic, and abdominal region). CT measurements were performed for each segment at three insufflation pressures (0, 5, and 10 mmHg). The cervical segment was assessed at the level of the 4^{th} cervical vertebrae. The thoracic inlet segment was at the first thoracic vertebrae level, the heart base segment was at the carina region, the caudal intrathoracic segment was at the level of seventh to eighth thoracic vertebrae, and the abdominal segment was 2cm cranial to the gastroesophageal junction. The measurements were obtained at five predetermined esophageal sites to determine the for cross−sectional luminal area (cm^2) and wall thickness (cm) using transverse images. Representative images were unenhanced and contrast−enhanced at comparable anatomic levels. Images were reviewed in a soft tissue window with manual adjustments to maximize conspicuity of the esophageal wall. These measurements were conducted at a sufficient magnification for CT images. In addition, multiplanar reconstructions (MPR) and curved MPR images were obtained, and the esophageal lumen was imaged virtually to generate endoluminal views using a dedicated image processing workstation (Vitrea®2, Vital Images, Inc., Minnesota, United States).

5. Statistical analyses

Statistical analyses were performed using standard software (IBM SPSS Statistics for Windows, Version 23.0, IBM Corp., Armonk, NY). To verify the effect of insufflation pressure, the paired Wilcoxon-signed rank test was used to compare the mean differences between insufflation pressures of 0, 5, and 10 mmHg for cross-sectional areas and wall thickness in each part. The luminal cross-section of each esophageal segment at 5 mmHg and 10 mmHg and the differences in esophageal wall thickness of the segments at all insufflation pressures were compared using Kruskal-Wallis test followed by a post hoc Mann-Whiney U-test with Bonferroni correction, respectively. The Pearson correlation analysis was used to determine the relationship between the cross-sectional area and wall thickness at all insufflation pressures. The Wilcoxon test was conducted for the determination of esophageal wall thickness at each of the esophageal portions before and after exposure to the contrast agent after gas insufflation. A value of $P < 0.05$ was considered significant.

Results

1. Esophageal insufflation CT (EICT)

In this experiment, EICT was applied successfully for distention of the canine esophagus in addition to the conventional CT. No clinical challenges were associated with CT scan or anesthesia, as the dogs recovered from anesthesia without any serious complication. The scan duration was 9.8 to 10.9 sec (mean, 10.76 sec; SD, ± 0.25). The total scan duration was less than 10 min for each dogs including procedures such as insertion of Foley catheter and contrast media injection. The insufflation time including the scan duration was less than 30 sec suggesting that the insufflation pressure gauge was consistent over short durations at a pressure of 5 mmHg, although insufflation pressure gauge was not maintained consistently at a pressure of 10 mmHg.

2. Imaging for EICT

In the experimental dogs, the esophageal lumens were not adequately visualized before gas insufflation due to the collapse of esophagus. After gas insufflation, appropriate esophageal distention was observed at 5 and 10 mmHg (Fig. 2). Significant differences were found in the esophageal luminal cross-sectional areas among three groups ($p < 0.05$, respectively). Significant differences in esophageal wall thickness were detected at pressure of 0 and 5 mmHg and at 0 and 10 mmHg ($P < 0.05$, respectively). The mean areas in the esophageal lumen were larger under pressures compared with absence of insufflation, and esophageal wall thickness tended to be smaller under pressure. Esophageal (but not gastric) distention was established and maintained at 5 mmHg. At 10 mmHg, the pressure was also adequately maintained and more distended than at 5 mmHg. However, all dogs showed gas distention of the stomach after initiation of esophageal insufflation. Summary data of measured values obtained at insufflation pressure of 0, 5, and 10 mmHg were recorded (Table 1). Furthermore, it was found that a significant negative correlation of esophageal wall thickness with luminal cross-sectional area ($r = -0.752$, $p < 0.001$). A few variables differed significantly among each esophageal segments at 5 and 10 mmHg, the luminal areas in the thoracic inlet, heart base, and abdominal portion were significantly lower than the others segments ($P < 0.01$). Compared with the esophageal wall thickness of each segment, the abdominal portion of the esophageal wall thickness was significantly thicker than at the other portions in pre-insufflation ($P < 0.01$). However, no statistically significant differences were found at pressures of 5 and 10 mmHg. Following intravenous administration of contrast medium, uniformly moderate contrast enhancement of the esophageal wall was observed at 5 and 10 mmHg. Esophageal wall conspicuity was better with contrast-enhanced imaging compare with unenhanced images when it was surrounded by adjacent soft tissues such as fat and muscles (Fig. 3). Contrast enhancement did not affect the thickness measurements of any esophageal wall.

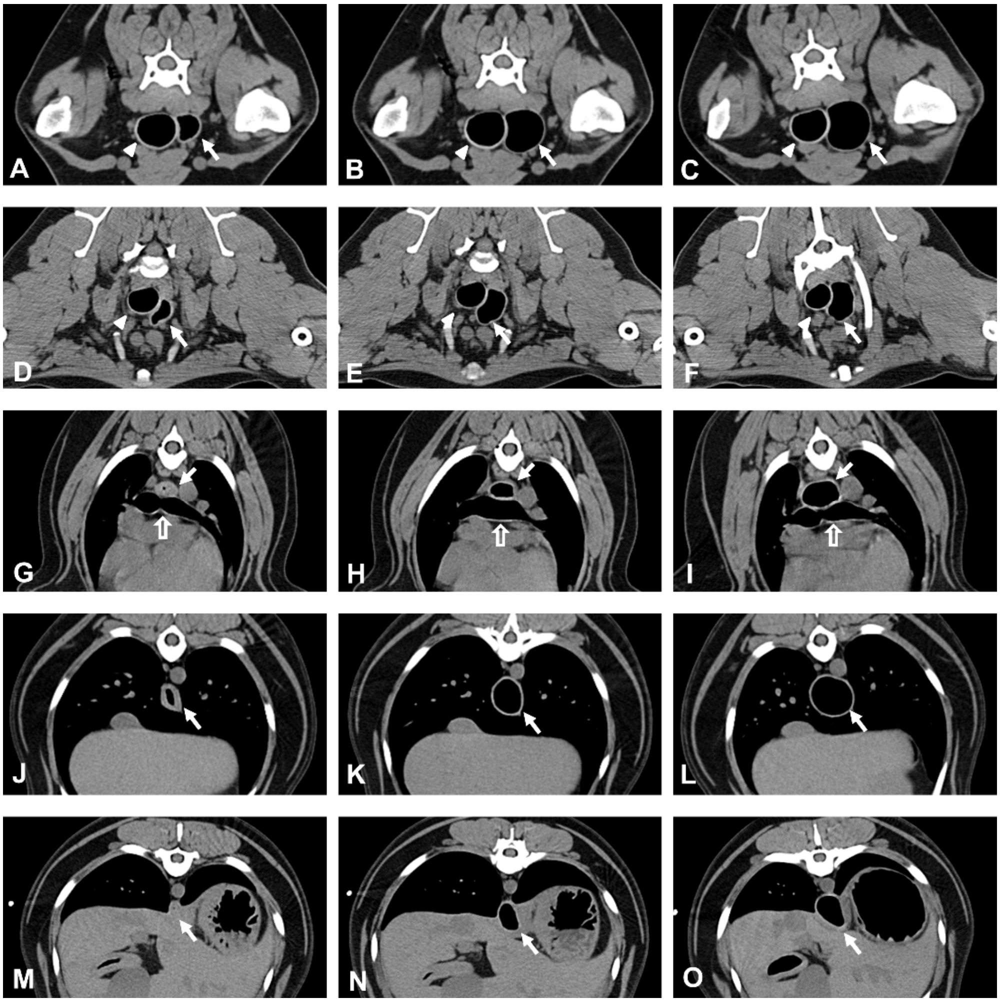

Fig. 2. Unenhanced CT images of the esophagus at pressures of 0, 5, and 10 mmHg. After gas insufflation of the esophagus (arrow), significant esophageal distention was identified at pressures of 5 and 10 mmHg compared with 0 mmHg. (A, D, G, J, M): 0 mmHg; (B, E, H K, N): 5 mmHg; (C, F, I, L, O): 10 mmHg. *First row*: cervical segment. *Second row*: caudal intrathoracic segment. *Third row*: carina segment. *Fourth row*: caudal intrathoracic segment. *Fifth row*: abdominal segment. Arrowheads and open arrows indicate the trachea and tracheal bifurcation, respectively.

Table 1. Each Pressure Group: Summary Statistics (Mean ± SD)

	Insufflation Pressure			P-Value		
	0 mmHg	5 mmHg	10 mmHg	0 vs.5	0 vs.10	5 vs.10
Cervical						
Luminal cross-sectional area (cm^2)	1.44±0.31	4.11±0.29	4.99±0.17	0.018	0.018	0.018
Wall thickness (cm)	0.15±0.02	0.11±0.01	0.09±0.01	0.043	0.018	0.237
Thoracic inlet						
Luminal cross-sectional area (cm^2)	0.49±0.20	2.47±0.24	3.54±0.28	0.018	0.018	0.018
Wall thickness (cm)	0.18±0.02	0.12±0.01	0.09±0.01	0.028	0.018	0.042
Heart base						
Luminal cross-sectional area (cm^2)	0.18±0.09	1.98±0.33	3.42±0.43	0.018	0.018	0.018
Wall thickness (cm)	0.19±0.02	0.13±0.01	0.09±0.01	0.018	0.018	0.028
Cd. intrathoracic						
Luminal cross-sectional area (cm^2)	0.91±0.36	4.26±0.32	5.26±0.30	0.018	0.018	0.018
Wall thickness (cm)	0.22±0.02	0.11±0.01	0.09±0.01	0.018	0.018	0.075
Abdominal						
Luminal cross-sectional area (cm^2)	0.22±0.11	2.42±0.34	3.37±0.37	0.018	0.018	0.018
Wall thickness (cm)	0.29±0.02	0.15±0.01	0.13±0.01	0.018	0.018	0.028

Cd., caudal; cm, centimeter; mmHg, millimeter mercury.

Fig. 3. Contrast enhanced images of the esophagus insufflated at pressures of 5 (A, C, E, G, I) and 10 (B, D, F, H, I) mmHg at cervical (A, B), thoracic inlet (C, D), carina (E, F), caudal intrathoracic (G, H), and abdominal (I, J) levels. The distended esophagus was observed (arrow). After contrast medium administration, the esophageal wall was enhanced and the wall conspicuity was increased compared with the unenhanced image, especially, when esophagus was surrounded by adjacent soft tissue such as fat and muscles (A, B, C, D). Arrowheads indicate the trachea.

3. Image reconstructions

MPR and curved MPR were used to characterize the distended esophagus, the entire esophageal lumen was seen in a single cross-sectional image (Fig. 4B, D). In addition, virtual endoscopy was not obstructed by the distended esophageal lumen, and it facilitated visualization from several different angles independent of operator skill unlike conventional endoscopy.

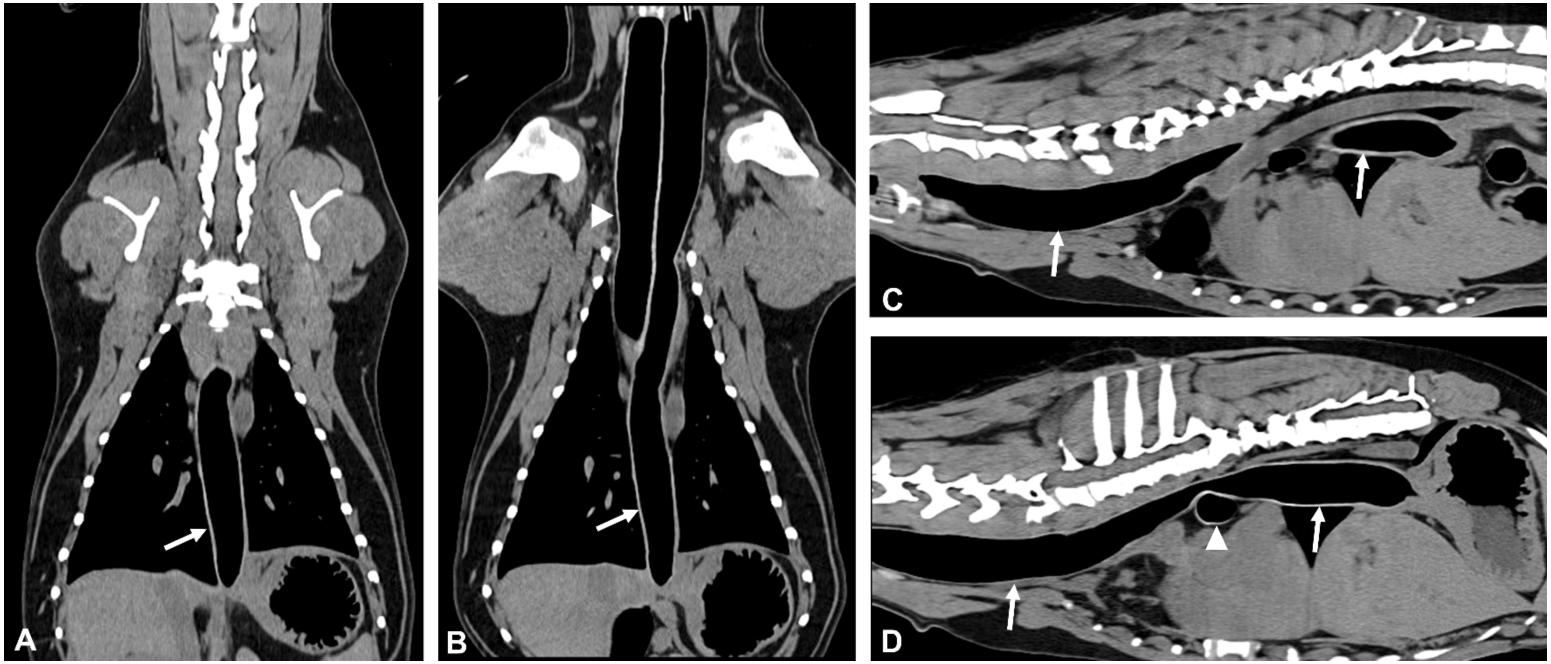

Fig. 4. Unenhanced (A, B) dorsal and (C, D) sagittal images of the esophagus after insufflation at a pressure of 5 mmHg in dog. Curved multiplanar reconstruction (MPR) images (B, D) show the entire esophageal lumen in one cross−section compared with simple MPR (A, C). The luminal diameter in the heart base of the esophagus was less than at the other portions on a curved sagittal image (D, arrowhead level). arrows, esophagus; arrowheads, trachea.

Discussion

The present study shows that EICT can be safely and effectively used in normal dogs between 5 mmHg and 10 mmHg for esophageal distention during CT examination. Using this technique, the esophagus was distended to the appropriate level. Greater mean esophageal luminal areas were detected at insufflation under any pressure, and the esophageal wall thickness was inversely correlated with insufflation pressure compared with lack of insufflation. Although esophageal lumen at 10 mmHg was more distended than at 5mm Hg, the esophageal distention was established and maintained at a pressure of 5 mmHg. And the stomach was dilated with gas at a pressure of 10 mmHg, but not at5 mmHg in the present study.

In veterinary medicine, the most frequent modalities used to study esophageal lesions include contrast esophagography and endoscopy, which are associated with limitations (Guiford, 2005, Kirberger *et al.*, 2012). Currently, CT increasingly used as a superior imaging tool in diagnostic veterinary medicine. However, conventional CT for hollow organs such as esophagus has a limited role in evaluating lumen and luminal walls. In this investigation, adequate esophageal distention was obtained via EICT and easily facilitated curved MPR and virtual endoscopic imaging. Appropriate gaseous distention is critical to evaluate wall thickness and perform virtual endoscopy accurately in CT examination of the esophagus (Onbaş *et al.*, 2006).

In conventional CT, esophageal collapse prevents easy delineation of anatomy. In contrast, EICT allows survey of the entire direction, location and wall of the esophagus. And uniform contrast enhancement of the esophageal wall was identified after contrast medium injection, the wall conspicuity surrounded by adjacent soft tissue was increased. Although the present study was only performed under contrast enhancement by manual injection, additional phase investigation can be used to differentiate the detailed esophageal lesions. CT images showing a relatively post-contrast hypoperfusion increase the risk of neoplastic transformation in canine spirocercosis-induced esophageal nodules using the triple-phase dynamic CT (Kirberger *et al.*, 2015).

In the present study, the esophageal luminal cross-sectional areas in the thoracic inlet, heart base, and abdominal portions were fewer than the other segments with extra-esophageal structures restricting esophageal distention. Esophageal foreign bodies are most commonly found in the thoracic inlet, heart base, and abdominal segments (Kyles, 2013). An increase in esophageal wall thickening at the abdominal portion correlated with the accepted location of the high pressure area at the gastroesophageal junction relate to the caudal esophageal sphincter (Baloi *et al.*, 2013; Evans and Lahunta, 2013; Kyles, 2013). However, there were no significant differences between the five different sites of each of the esophageal segments at pressures of 5 and 10 mmHg. It may be attributed to the thinning of wall under esophageal luminal distention, which facilitates the detection of small lesions or subtle changes associated with the esophageal wall.

In anesthetized dogs the resting caudal esophageal sphincter pressure was 21 ± 10 cm H_2O (15.45 ± 7.36 mmHg, mean ± SD). The pressure of resting sphincter reflects the pressure in the closed sphincter, and the intragastric opening pressure is slightly higher than that of the resting sphincter pressure when caudal esophageal sphincter is open. However, the selection and accurate measurements correlated with sphincter competence was a challenge because gastric wall tension and length of the sphincter muscle contributing to sphincter opening (Pettersson *et al.*, 1980). In the present study, it was observed that the stomach was dilated with gas and caudal esophageal sphincter was opened only at 10 mmHg in all dogs. Despite the complexity of the dynamic of sphincter function, it was speculated that the intraesophageal pressure exceeded the pressure of caudal esophageal sphincter, and the sphincter muscle was opened following gastric insufflation of CO_2 at 10 mmHg. Automatic insufflation occurs when pressure sensors continuously measure the pressure and gas when the measured pressure falls below the target pressure. Therefore, the insufflation pressure gauge was not maintained consistently due to the gas entering the stomach continuously. The esophagus was sufficiently distended at a pressure of 5 mmHg, which is considered appropriate as initial pressure, except for the regions of interest such as gastroesophageal junction and stomach, which need high pressure.

In a previous CT pneumocolonography study of normal dogs, body positioning did not significantly affect luminal cross-section and wall thickness, and scanning was conducted during a positive-pressure breath-hold (Steffey *et al.*, 2015). However, in the present study, it was conducted in sternal recumbency during transient apnea to obtain optimal esophageal distention. Esophageal pressure is affected by lung volume and other mediastinal structures. In the human study, in the supine position, the heart and great vessels might be expected to compress the esophagus under gravity thereby increasing esophageal pressure. Esophageal pressure and lung volume show negative relationship with each other. Transient apnea induction by manual hyperventilation resulted in end-expiratory lung volume (Ferris *et al.*, 1959). Therefore, for the maximal distention of esophagus, it may require sternal position and end-tidal lung volume. In the present study, despite a short scan duration and absence of procedural difficulties, these parameters were carefully addressed in patients diagnosed with cardiorespiratory disease.

No major adverse events are associated with CO_2 insufflation of esophagus for CT in humans (Ulla *et al.*, 2013). During laparoscopy, CO_2 is the most commonly used gas for pneumoperitoneum. It is a very soluble gas with a rapid diffusion in the blood and body tissues and subsequent exhalation, however, it may lead to hypercapnia and acidosis (Fukushima *et al.*, 2011). It is possible that esophageal insufflation of CO_2 may be associated with these complications. However in my study, adverse effects of EICT were not observed and the dogs recovered uneventfully. This procedure including CO_2

insufflation was carried out in a very short time and the amount of insufflated CO_2 was small compared with laparoscopy (Fukushima *et al.*, 2011). And CO_2 insufflation during diagnostic or therapeutic endoscopy has been shown to be safe and effective in reducing procedure-related pain and discomfort in humans. There were no adverse events such as pulmonary complications or CO_2 retention occurred with CO_2 insufflation (Maeda *et al.*, 2016). Although EICT is a simple, safe and rapid method, careful monitoring is needed including measurements of heart rates, blood pressures and end-tidal CO_2 levels during the procedure.

The present study has a few limitations. This developed technique (EICT) requires additional equipment such as a mechanical insufflator, which is not needed in conventional CT. However, EICT facilitates effective distention of the esophagus.

Furthermore, the study included only normal dogs without esophageal lesions, which were subjected to EICT. The recommended protocol may not be applicable to the esophagus of dogs with lesions that may have different esophageal wall compliance or partial obstructions due to large lesions. Such a cases may require higher insufflation pressures or positional changes including lateral recumbencies. Therefore additional studies are needed to determine whether the EICT enhanced esophageal lesions in dogs and standardization of this technique may increase its diagnostic value. In addition, that the degree of gastric distention due to EICT was not investigated in the present study, additional studies are needed using EICT to distend the stomach to gas at pressures of 10 mmHg or greater.

In conclusion, EICT is a feasible technique that can consistently distend the canine esophagus. Based on the present study, it was recommend a clinical protocol for EICT application for in clinical canine patients an initial insufflation pressure of 5 mmHg except in the gastroesophageal junction, in which case a higher pressure such as 10 mmHg may be required. Reconstruction of additional images using virtual endoscopy facilitates comprehensive assessment of the esophageal lesion. EICT can be considered an useful and non-invasive imaging technique for evaluating esophageal and extraesophageal disease in a single setting.

References

Baloi PA, Kircher PR, Kook PH. Endoscopic ultrasonographic evaluation of the esophagus in healthy dogs. AM J Vet Res. 2013;74:1005–1009.

Brissot HN, Burton CA, Doyle RS, Bray JP. Caudal mediastinal paraesophageal abscesses in 7 dogs. Vet surg. 2012;41:286−291.

Evans HE, De Lahunta A. The disgestive apparatus and abdomen. In: Miller's Anatomy of the Dog, 4ed. St. Louis: Elsevier Saunders, 2013:304−307.

Ferris BG, Mead J, Frank NR. Effect of body position on esophageal pressure and measurement of pulmonary compliance. J Appl Physiol. 1959;14:521−524.

Fukushima FB, Malm C, Andrade ME, Oliveira HP, Melo EG, Caldeira FM, Gheller VA, Palhares MS, Macedo SP, Figueiredo MS, Silva MX.

Cardiorespiratory and blood gas alterations during laparoscopic surgery for intra-uterine artificial insemination in dogs. Can Vet J. 2011;52:77-79.

Guiford WG. Upper gastrointestinal endoscopy. In: Constantinescu GM, McCarthy TC, eds. Veterinary endoscopy for the small animal practitioner. St. Louis: Elsevier Saunders, 2005:279-321.

Hoey S, Drees R, Hetzel S. Evaluation of the gastrointestinal tract in dogs using computed tomography. Vet Radiol Ultrasound. 2013;54:25-30.

Kirberger RM, Cassel N, Stander N, McLean M, Dvir E. Triple phase dynamic coumputed tomographic perfusion characteristics of spirocercosis induced esophageal nodules in non-neoplasitic versus neoplastic canine cases. Vet Radiol Ultrasound. 2015;56:257-263.

Kirberger RM, van der Merwe LL, Dvir E. Pneumoesophagography and the appearance of masses in the caudal portion of the esophagus in dogs with spirocercosis. J Am Vet Med Assoc. 2012;240:420-426.

Kyles AE. Esophagus. In: Tobias KM, Johnston SA, eds. Veterinary surgery: small animal: 2-Volume Set: St. Louis: Elsevier Saunders, 2013:1461-1483.

Liu BR, Liu BL, Wang XH, Zhan L, Liu LL, Song JT, Du B, Cui L, Liu SQ. Esophageal insufflation computed tomography for the diagnosis and management of esophageal submucosal tumors. Surg Endosc. 2017;31:2350-2355.

Maeda Y, Hirasawa D, Fujita N, Ohira T, Harada Y, Yamagata T, Koike Y, Suzuki K. Carbon dioxide insufflation in esophageal endoscopic submucosal dissection reduces mediastinal emphysema: A randomized, double-blind, controlled trial. World J Gastroenterol. 2016;22:7373-7382.

Mazzeo S, Caramella D, Gennai A, Giusti P, Neri E, Melai L, Cappelli C, Bertini R, Capria A, Rossi M, Bartolozzi C. Multidetector CT and virtual endoscopy in the evaluation of the esophagus. Abdom Imaging. 2004;29:2-8.

Onbaş O, Eroglu A, Kantarci M, Polat P, Alper F, Karaoglanoglu N, Okur A. Preoperative staging of esophageal carcinoma with multidetector CT and virtual endoscopy. Eur J Radiol. 2006;57:90-95.

Petite A, Kirbergr R. Mediastinum. In: Schwarz T, Saunders J, eds. Veterinary computed tomography; Chichester: John Wiley & Sons, 2011:249-260.

Pettersson GB, Bombeck CT, Nyhus LM. The lower esophageal sphincter: mechanisms of opening and closure. Surgery. 1980;88:307-314.

Steffey MA, Daniel L, Taylor SL, Chen RX, Zwingenberger AL. Computed tomographic pneumocolonography in normal dogs. Vet Radiol Ultrasound. 2015;56:278-285.

Terragni R, Vignoli M, Rossi F, Laganga P, Leone VF, Graham JP, Russo M, Saunders JH. Stomach Wall Evaluation Using Helical Hydro-CT. Vet Radiol Ultrasound. 2012'53:402-405.

Vignoli M, Saunders J. Gastrointetinal tract. In: Schwarz T, Saunders J, eds. Veterinary computed tomography: Chichester: John Wiley & Sons, 2011:325-330.

Ulla M, Cavadas D, Muñoz I, Beskow A, Seehaus A, García-Mónaco R. Esophageal cancer: pneumo-64-MDCT. Abdom Imaging. 2010;35:383-389.

Ulla M, Gentile EMJ, Cavadas D, Yeyati EL, Frank L, Argerich JI, Garcia Mónaco R. Esophageal cancer characterization with pneumo-64-MDCT. Abdom Imaging. 2012;37:501-511.

Ulla M, Gentile E, Yeyati EL, Diez ML, Cavadas D, Garcia-Monaco RD, Ros PR. Pneumo-CT assessing response to neoadjuvant therapy in esophageal cancer: Imaging-pathological correlation. World J Gastrointest Oncol. 2013;5:222-229.

Yamada K, Morimoto M, Kishimoto M, Wisner ER. Virtual endoscopy of dogs using multi-detector row CT. Vet Radiol Ultrasound. 2007;48:318-322.

국문 초록

개의 전산화단층촬영에서 식도 가스 주입 기술의 평가

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Conventional CT에서 식도와 같은 관상장기는 정상적으로 허탈된 상태로 존재하여 내강 및 벽을 평가하는데 있어 제한점을 가지고 있다. 수의에서 식도 내강을 확장시키기 위해서 단순히 위관 튜브 혹은 기관 튜브를 이용하여 room air를 주사기를 이용하여 주입하는 방법이 보고 되어 있으나 지속적으로 만족할 만한 수준으로 확장시키는 방법에 대한 보고가 없다. 따라서 본 연구에서 electronic insufflaotr를 이용하여 이산화탄소 가스

주입을 통한 방법 (Esophageal Insufflation Computed Tomography, EICT) 을 통해 식도 내강을 확장시키는 방법에 대해 평가하고자 하였다.

7마리의 건강한 비글견을 사용하였으며 EICT 전 conventional CT 촬영을 실시하였다. EICT는 과환기를 통해 일시적 무호흡을 유발하고 steranl recumbency 자세에서 electronic insufflator를 이용하여 0, 5, 그리고 10 mmHg의 압력의 이산화탄소 가스 주입을 통해 실시하였다. 그리고 혈관내 300 mgI/ml 의 농도의 조영제를 600 mgI/kg의 용량으로 manual로 주입하였다. 각 압력에서 CT 영상을 얻은 후, 식도를 다섯 부분 (경부, 흉곽 입구, 심기저부, 흉부 뒷부분, 복부 부분) 으로 구분하여 각 부분에서의 식도 내강 면적과 식도벽의 두께를 측정하였다. 5와 10 mmHg의 압력에서 이산화탄소 가스 주입시 식도 내강은 모두 적절한 수준으로 확장되는 것이 관찰 되었으며 압력이 증가하면서 식도 내강의 확장은 증가하고 식도벽의 두께는 감소하는 것이 확인되었다. 그리고 모든 개체에서 10 mmHg의 압력으로 가스를 주입할 시 위 내강도 동시에 확장되는 것이 관찰되었으며 5 mmHg의 압력에서는 그렇지 않았다. EICT를 통해 얻은 영상을 통해 곡선 다면재구성 (curved MPR)과 가상내시경 (virtual endoscopy) 영상의 변환도 수월히 진행되어 이를 통해 식도 병변의 명확한 평가가 가능할 것으로 고려되었다.

EICT는 안전하고 CT 촬영 중 식도 내강을 지속적으로 확장시킬 수 있

는 유용한 방법으로 식도 내강의 적절한 확장을 통한 CT 촬영을 통해 식도 병변의 명확한 평가가 가능할 것으로 생각된다. 그리고 이산화탄소 가스의 초기 주입 압력으로는 5 mmHg가 적당할 것으로 고려된다.

주요어: computed tomography, CO_2 insufflation, dog, esophagus

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